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METHODS FOR SWITCHING IMPULSE TESTS ON HIGH VOLTAGE INSULATORS

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Indian Standard

METHODS FOR SWITCHING IMPULSE TESTS ON HIGH-VOLTAGE INSULATORS

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Indian Standard

METHODS FOR SWITCHING IMPULSE TESTS ON HIGH-VOLTAGE INSULATORS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 26 November 1976, after the draft finalized by the Electrical Insulators and Accessories Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard has been prepared with a view to achieve the following objects:

a) To define the terms used,

b) To define switching impulse characteristics of insulators and to prescribe the conditions under which the specified values of these characteristics shall be verified, and

c) To prescribe methods for switching impulse tests on insulators under standard conditions.

0.3 The flashover and withstand voltages of insulators under service conditions may differ from the same voltages under standard conditions. This effect has been recognized with lightning impulse testing, but the effect of ambient conditions and of the arrangements of insulators and associated metal work is much greater with switching impulses (*see* **9** and **11**).

0.4 The term 'flashover' used in this standard includes flashover across the insulator surface as well as disruptive discharges by sparkover through air adjacent to the insulator. Disruptive discharges should occur only occasionally elsewhere (for example, to other structures or to earth), in which case they should not be taken into account for the purposes of this standard.

0.5 In the preparation of this standard, assistance has been derived from the IEC Pub 506(1975) ' Switching impulse tests on high-voltage insulators ', issued by the International Electrotechnical Commission.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard applies to switching impulse tests, when specified, on insulators (*see* **2.1**) intended for use on ac installations with highest voltage of 300 kV and above.

NOTE 1 — This standard is not intended to be applied to polluted insulators. A switching impulse test on polluted insulators is considered to be premature at the present state of the art.

NOTE 2 — This standard does not give numerical values for insulator characteristics, neither does it deal with the choice of insulators for specific operating conditions.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Insulator — An insulator shall be understood as an overhead-line insulator string or a post insulator or a bushing.

2.2 Dry or Wet Switching Impulse Withstand Voltage — The value of the switching impulse voltage which the insulator withstands under dry or wet conditions as prescribed in **12**.

2.3 Fifty Percent Dry or Wet Switching Impulse Flashover Voltage — The switching impulse voltage which, under the conditions prescribed in **12**, has a 50 percent probability of producing flashover on the insulator, dry or wet.

3. SWITCHING IMPULSE CHARACTERISTICS OF INSULATORS

3.1 An insulator is characterized as follows:

a) Outdoor insulator — The specified wet switching impulse withstands voltage; and

b) Indoor insulator — The specified dry switching impulse withstands voltage.

NOTE 1 — In certain cases and by special agreement, outdoor insulators may also be characterized by the specified dry switching impulse withstand voltage.

NOTE 2 — Usually, the specified impulse withstand voltage is selected from the values given in IS : 2165 (Part II)-1973* corresponding to the highest system voltage for which the insulator is intended.

4. VALUES OF SWITCHING IMPULSE VOLTAGES

4.1 In accordance with **5.1.2** of IS : 2071 (Part II)-1974† switching impulse voltages shall be expressed by their prospective peak values.

*Insulation co-ordination: Part II For highest voltages for equipment of 100 kV and above (*first revision*).

†Methods of high voltage testing: Part II Test procedures (*first revision*).

5. CLASSIFICATION OF THE TEST

5.1 The switching impulse test is a type test and shall be carried out using a standard mounting arrangement (*see* **11.1**). By agreement between the manufacturer and the user, an arrangement representing service conditions (*see* **11.2**) may also be used.

5.1.1 In the case of tests performed with the standard mounting arrangement, the tests need not be repeated if a certificate of previous tests is available.

6. TEST TECHNIQUE

6.1 The switching impulse voltage test technique shall be in accordance with **5** of IS : 2071 (Part II)-1974*.

7. STANDARD SWITCHING IMPULSE VOLTAGE

7.1 A 250 $\pm$ 50/2 500 $\pm$ 1 500 μs switching impulse voltage shall be used (*see* **5.2** of IS : 2071 (Part II)-1974*).

7.2 The value of the switching impulse voltage shall be its prospective peak value as measured by a method envisaged in IS : 2071 (Part II)-1974*.

8. STANDARD ATMOSPHERIC CONDITIONS

8.1 The standard atmospheric conditions for tests in accordance with **3.5.2** of IS : 2071 (Part I)-1974† are as follows:

Temperature	t_0	=	20°C
Pressure	b_0	=	1 013 mbar
Humidity	h_0	=	11 g water per m^3

NOTE — The pressure 1 013 mbar corresponds to a height of 760 mm in a mercury barometer at 0°C. If the height of the barometer is h mm of mercury, the atmospheric pressure in millibars is approximately:

$$b = \frac{1\,013\,h}{760} \text{ mbar}$$

Temperature correction for the height of the mercury column is considered to be negligible.

9. CORRECTION FACTORS FOR ATMOSPHERIC CONDITIONS

9.1 Withstand and flashover voltages depend on the atmospheric conditions at the time of test. If these conditions differ from the standard conditions (*see* **8**), correction factors K_d for air density and K_h for humidity shall be used as given in Table 1 to obtain the voltage to be applied in a withstand test or the voltage to be recorded in a flashover test.

*Methods of high voltage testing: Part II Test procedures (*first revision*).

†Methods of high voltage testing: Part I General definition and test requirements (*first revision*).

TABLE 1 CORRECTION OF VOLTAGES FOR ATMOSPHERIC CONDITIONS

(*Clause* 9.1)

TEST	ADJUSTMENT REQUIRED
(1)	(2)
Dry withstand	Multiply specified withstand voltage K_d and divide by K_h
Dry flashover	Divide measured flashover voltage by K_d and multiply by K_h
Wet withstand	Multiply specified withstand voltage by K_d
Wet flashover	Divide measured flashover voltage by K_d

9.2 Air Density Correction Factor K_d

9.2.1 For positive-polarity switching impulses, the air density correction factor K_d is given by:

$$K_d = \delta^m$$

where, if the atmospheric pressure b is expressed in millibars and the temperature t is expressed in degrees Celsius,

$$\delta = 0{\cdot}289 \frac{b}{273 + t}$$

and the exponent m is read from Fig. 1, as a function of the insulating distance d.

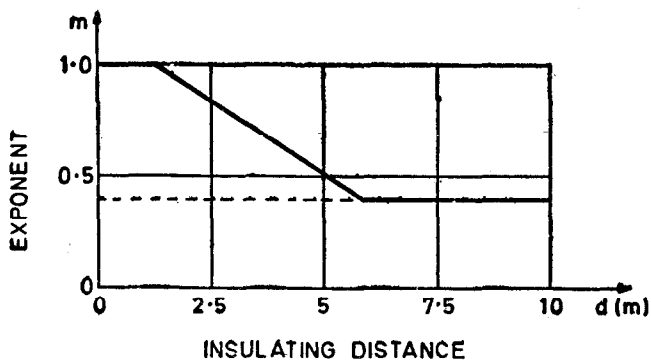

FIG. 1 CORRECTIONS FOR AIR DENSITY AND HUMIDITY EXPONENT m *Vs* INSULATING DISTANCE d

9.2.2 For negative-polarity switching impulses, very little information is available, and therefore no correction recommended, that is, $K_d = 1$.

9.3 Humidity Correction Factor K_h

9.3.1 No humidity correction shall be applied for wet tests, that is, $K_h = 1$.

9.3.2 For dry tests, with positive-polarity switching impulses, the following correction factor shall be applied:

$$K_h = K^m$$

where m and K are given in Fig. 1 and 2 respectively.

For dry tests, with negative-polarity switching impulses, very little information is available, and therefore no correction is recommended, that is, $K_h = 1$.

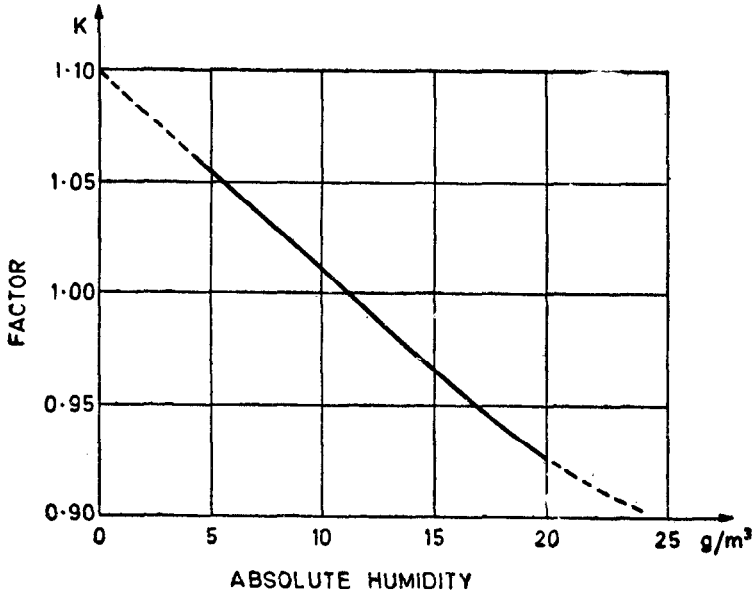

FIG. 2 CORRECTIONS FOR HUMIDITY FACTOR K VERSUS ABSOLUTE HUMIDITY

10. CONDITION OF THE INSULATOR

10.1 Before commencing the tests, the insulator shall be clean and dry and in thermal equilibrium with the ambient air.

10.2 For dry tests, precautions shall be taken to avoid formation of dew on the surfaces of the insulator, especially when the relative humidity is high. For example, the insulator shall be maintained at the ambient

temperature of the test location for sufficient time for equilibrium to be reached before the test starts. These precautions shall be observed particularly in outdoor tests. Except by agreement between the manufacturer and the user, dry tests shall not be made if the relative humidity exceeds 85 percent.

11. METHODS OF MOUNTING

11.1 Standard Mounting Arrangements

11.1.1 *Post Insulators* — The post insulator shall be mounted upright on a vertical earthed metal support. The upper part of the metal support shall have a square mounting surface with the width of each side between one and two times the diameter of the metal fitting at the base of the insulator under test.

11.1.1.1 The mounting surface of the metal support shall be placed at a height H above the ground, according to the following table:

Overall Height of Insulator	*Height H Above Ground*
mm	mm
≤2 500	2 500
>2 500	3 000
≤3 200	3 000
>3 200	4 000
≤4 200	4 000
>4 200	5 000

11.1.1.2 A horizontal cylindrical conductor shall be attached to the top of the insulator. The length of the conductor shall be at least equal to 1·5 times the height of the insulator and it shall extend equally on each side of the insulator axis. The diameter of the conductor shall be between 1·5 percent and 2 percent of the height of the insulator. To avoid sparkover from the two ends of the conductor, each end shall be protected by means of a suitable device (for instance, by means of a metal ring).

11.1.1.3 The test voltage shall be applied between the conductor and the earthed support, the high-voltage connection being made at one end of the conductor.

11.1.1.4 During the test, no object other than those described in this clause shall be nearer to the top of the post insulator than 1·5 times the height of the insulator.

11.1.1.5 The post insulator shall be complete with those parts which are considered necessarily associated with the insulator and are specified as such by the manufacturer.

11.1.2 *Overhead-line Insulators* — The insulator shall be suspended vertically in an arrangement simulating a tower body and cross-arm. The cross-arm is simulated by a horizontal member, the insulator being at one end and the vertical member simulating the tower body at the other. Both members and the link supporting the insulator shall be earthed. The width of each member facing the insulator shall be at least 20 percent of the length of the insulator. The distance between the axis of the insulator and the vertical member simulating the tower body shall be between 1·2 and 1·5 times the length of the insulator. The distance between the uppermost point of the insulator and the lower part of the horizontal member simulating the tower body shall extend at least twice the length of the insulator below the member simulating the tower cross-arm.

11.1.2.1 A conductor bundle, consisting of two sub-conductors in the form of straight smooth metal rods or tubes, shall be attached to the lower integral fittings of the insulator at right angles to the cross-arm. The two sub-conductors of the bundle shall be maintained parallel by means of horizontal spacers; the sub-conductor spacing shall be about equal to one-tenth of the length of the insulator. The bundle conductor shall extend approximately the length of the insulator on each side of the insulator axis, and the diameter of each sub-conductor shall be between 0·75 and 1·25 percent of the length of the insulator. To avoid spark-over from the two ends of the bundle conductor, each end shall be protected by means of a suitable device (for instance, by means of a metal ring). The height of the conductor above ground shall be equal to about 1·5 times the length of the insulator but not less than 6 m.

11.1.2.2 The test voltage shall be applied between the conductor bundle and earth, the high-voltage connection being made at one end of the conductor bundle.

11.1.2.3 During the test, no object other than those described in this clause shall be nearer to the live end of the insulator than 1·5 times the length of the insulator.

11.1.2.4 The insulator shall be complete with those parts which are considered necessarily associated with the insulator and are specified as such by the manufacturer.

NOTE — For insulator strings longer than 5 m, it may be necessary to modify some standard dimensions, in particular the number and spacing of the sub-conductors in the bundle.

11.1.3 *Bushings* — In addition to the general recommendations for the condition of the bushings when dielectric tests are made (*see* IS : 2099-1973*), the following requirements shall be complied with the switching impulse tests:

The bushing shall be mounted on an earthed plane extended radially from the axis of the bushing at least 0·4 L in every direction, L being the dry

*Specification for bushings for alternating voltages above 1 000 V (*first revision*).

arcing distance of the bushing. The high-voltage connection shall extend in line with the axis of the bushing to a point at least 0·4 L above the top of the bushing.

In the case of bushings of which one end is immersed, the details of the immersion shall be subject to agreement.

11.2 Mounting Arrangement Simulating Service Conditions — When tests are made under simulated service conditions (*see* **5**), the extent to which service conditions are imitated shall be agreed between the manufacture and the user, taking into account all factors which may influence the switching impulse performance of the insulator.

NOTE — The values measured under these conditions may differ appreciably from the values measured using the standard methods of mounting (*see* **11.1**).

12. PROCEDURE FOR VERIFYING THE SWITCHING IMPULSE WITHSTAND VOLTAGE

12.1 Dry Switching Impulse Test — The insulator shall be tested under the conditions prescribed in **10** and **11**. The impulse generator shall be adjusted to produce a 250/2 500 μs impulse (*see* **7**).

12.1.1 Impulses of both positive and negative polarity shall be used.

12.1.2 Two procedures are available for verifying the switching impulse withstand voltage namely the 50 percent flashover procedure and the withstand procedure.

12.1.3 The 50 percent flashover procedure is preferable for statistical reasons but it is not applicable to non-self-restoring insulations. The 50 percent flashover procedure shall therefore be applied to overhead-line, insulators and post insulators and the withstand procedure shall be applied to bushings.

NOTE — Particularly, when performing dry tests, some difficulties may sometimes occur in applying the 50 percent flashover procedure because of sparkovers elsewhere than on the insulator. If such difficulties occur, or if insulators are tested which are considerably longer than the minimum length nesessary to meet the switching impulse requirements, the withstand procedure may, be special agreement, be adopted for overhead-line and post insulators.

12.1.4 *Fifty Percent Flashover Procedure* — The 50 percent switching impulse flashover voltage shall be determined by the following procedure:

A voltage U_k is chosen, estimated to lie at or near the 50 percent flahsover voltage level. A voltage interval ΔU approximately 3 percent of U_k is also chosen.

One impulse is applied at the level U_k. If this does not cause flashover, the level of the next impulse should be $U_k + \Delta U$. If flashover occurs at the level U_k the next impulse should have a level $U_k - \Delta U$.

This procedure is repeated a number of times, each impulse having a level determined by the effect of the preceding impulse.

The number of impulses n_v applied at each voltage level U_v is counted and the 50 percent flashover voltages is determined as:

$$U_{50} \text{ percent} = \frac{\Sigma n_v U_v}{\Sigma n_v}$$

In this equation, the first level to be taken into account should be one at which two or more impulses were applied. This partially corrects for the error which may be introduced if U_k is much too low or much too high. The total number of impulses taken into account (Σn_v) shall be equal to 30.

The 50 percent switching impulse flashover voltage, determined by the above procedure, shall be corrected in accordance with **9**.

The insulator passes the test if the 50 percent switching impulse flashover voltage is not less than 1·078 times the specified switching impulse withstand voltage.

NOTE 1 — The specified switching impulse withstand voltage, in agreement with IS : 2165 (Part II) - 1973*, is taken as a voltage giving a 90 percent withstand probability. The 50 percent flashover value then corresponds to 1·078 times the withstand value for a standard deviation of 6 percent.

NOTE 2 — An alternative test procedure, which can be used mainly for research purposes, is the following:

A number of switching impulses are applied at each of several test voltage levels, the steps in voltage being 2 to 4 percent of the expected 50 percent flashover voltage.

The value of the 50 percent flashover voltage is found from a curve of flashover probability versus prospective test voltage, obtained by plotting the test results on probability paper as a straight line based on interpolation according to the least square law.

The 50 percent flashover voltage obtained by this procedure may be used for the purposes of this standard provided that at least 15 impulses are applied at each voltage level and at least four test voltage levels resulting in more than zero and less than 100 percent flashover are considered.

12.1.2 *Withstand Procedure* — A withstand test shall be performed at the voltage obtained from the specified switching impulse withstand voltage by applying the corrections for atmospheric conditions (*see* **9**). Fifteen impulses shall be applied to the insulator under test. If the number of flashover on the external insulation does not exceed two, the insulator is deemed to comply with this standard.

12.1.2.1 The time intervals between consecutive applications of the voltage shall be sufficient to avoid effects from the previous application of voltage in flashover or withstand tests.

12.1.2.2 The insulator shall not be damaged by these tests but slight marks on the surface of the insulating parts or chipping of the cement or other material used for assembly shall be permitted.

*Specification for insulation co-ordination : Part II For highest voltages for equipment of 100 kV and above (*first revision*).

12.2 Wet Switching Impulse Test — In addition to the requirements given in **12.1**, the following conditions shall be complied with:

The insulator, arrangement as prescribed in **10** and **11**, shall be exposed, before application of voltage and throughout the test, to artificial rain.

The characteristics of the artificial rain shall be in accordance with the recommendations of IS : 2071 (Part I)-1974*, which are summarized as follows:

a) Average precipitation rate for all measurements, horizontal component and vertical component	1·0 to 1·5 mm/min
b) Limits for any individual measurement and for each component	0·5 to 2·0 mm/min
c) Temperature of collected water	ambient temperature $\pm$ 15°C,
d) Water resistivity, measured at or corrected to 20°C	100 $\pm$ 15Ωm.

The measurement of the rate of precipitation shall be made near the top, middle and bottom of the object under test.

The test object should be pre-wetted initially for 15 minutes under the above specified conditions for the rain (which may, however, include the time needed for adjustment) and these conditions should remain unchanged throughout the test. The pre-wetting time may be reduced if special means are used to ensure effective wetting or when repeat tests are made at short intervals.

*Methods of high voltage testing: Part 1 General definitions and test requirements (*first revision*).

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